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A pilot project to store carbon as biomass in African woodlands

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SUMMARY

Capturing carbon by planting trees is a cost-effective way to store carbon, especially if linked to protection of existing woodlands. We describe a way to motivate African farmers to plant trees and protect woodland, based upon a Mozambican pilot project in the voluntary carbon market. By late 2009, 1510 farmers were enrolled. Between 2003-2009, the project was able to sell carbon credits totalling around 1.3 million $ on the voluntary carbon market, corresponding to 156 thousand tonnes of CO_2, at a price that averaged 9.0 $ per tonne. Moreover, the effect of the carbon project was to increase rural employment from 8.6% to 32%, whilst 73% of households raised commercial crops compared to 23% previously. There was also a notable development of social capital, with a measurable increase in literacy and the development of a business ethos with associated practical skills.

KEY WORDS

REDD, miombo, sustainable development, community forestry, carbon

INTRODUCTION

Forests and woodlands contain vast stores of carbon, and it has always been clear that the planting of trees on non-forested land, and the prevention of deforestation are likely to be one of the most cost-effective ways to reduce the build-up of carbon dioxide in the atmosphere [1]. Indeed, the 1997 Kyoto Protocol recognises this in its Article 3 although a policy directly related to preventing deforestation is excluded. In the case of the tropics, the recent deforestation rate accounts for 1-2 billion tonnes of carbon transferred to the atmosphere each year [2], enough to substantially increase rates of global warming. In 2005 at the conference of the UN Framework Convention on Climate Change (UNFCCC), the Coalition of Rainforest Nations initiated a request to consider 'reducing emissions from deforestation in developing countries', and by 2009 the UNFCCC reached an accord on a series of measures collectively known as REDD (Reduced Emissions from Degradation and Deforestation). Since then, there has been on-going discussion of the best way to achieve REDD, with emphasis on securing finance from international agencies including the World Bank, UNDP, UNEP and FAO, and from national governments.

Meanwhile, a number of projects designed to curb deforestation and degradation in Africa and elsewhere have been active as part of the voluntary carbon market (VCM) [3]. The VCM has developed independently of the Kyoto Protocol and is a means whereby organisations or individuals can offset their carbon emissions and receive certificates of Voluntary Emissions Reductions, VERs [4]. Only a few of these carbon projects have run for a sufficiently long period to be able to 'learn lessons' which may be valuable as funding for REDD develops. In this paper we aim to use the experience of a specific 5-year pilot project in Mozambique to (i) provide new data on the costs of creating carbon offsets in tropical landscapes, based on actual carbon sales in the voluntary carbon market (ii) identify the major difficulties and challenges that have been encountered and (iii) discuss future developments and prospects for this approach to climate abatement.

The carbon project was originally developed to test the applicability of the Plan Vivo to the African situation. Plan Vivo is a community-based carbon crediting system which rewards farmers for planting trees and conserving woodland with a view to assisting sustainable development [100], developed several years ago in quite different conditions in Mexico [101]. The carbon project was made possible with a European Union grant to assist the research component of the project in the pilot phase 2003-2008. The criteria for success of the project were: carbon stocks of miombo woodland should be measured, agroforestry systems should be established, baselines defined, carbon sales should be at least $200,000 and there should be significant co-benefits to the community.

PROJECT AREA

The area of the carbon project is the Sofala province of Mozambique, an area known as the Comunidade do Regulo Chicale. The project was initiated in Nhambita village, where the headquarters (base camp) was established. The study area of 558 km^2 is a rectangle: to the north-west 18.82°S, 33.90°E; to the south-east 19.21°S, 34.26°E. Of this, the carbon project currently occupies 1,500 farms and 100 km^2 of forest, the rest being available for further development and to evaluate any project leakage.

The climate falls into Köppen class Aw (tropical savanna), being sub-tropical with alternating cool-dry winters (April-October) and hot-wet summers (November-March). The rainfall measured 25 km away at Chitengo for the years 1956-1969 and 1998-2007 was 850 ± 269 mm/yr (mean and standard deviation).

The vegetation consists of tropical woodland, savanna, secondary woodland, riverine forest and cultivated plots of subsistence agriculture called machambas, each machamba being 1-3 hectares. The woodlands are classified as miombo, a type of savanna woodland occupying 2.7 million km^2 in southern Africa. Miombo woodlands are subject to frequent burning, associated with slash and burn agriculture, and their carbon stocks are believed to be lower than the biological potential for the region. After fire, most of the tree species re-sprout, but the rate of re-growth is inherently low, and limited by the poor soils and the low and unreliable rainfall of the region [5].

The human population occupies widely scattered homesteads, each with several buildings made of bamboo or poles, grass and mud, usually with livestock (chickens, ducks, goats, pigs), bananas and fruit trees (mango, papaya) with a central area for cooking. The main activities are subsistence farming, wood-gathering, hunting and preparing food. Until recently there were no shops, and school houses were primitive –sometimes with no roof. Wood is collected for firewood by a human population which has grown recently, particularly following the end of the civil war in 1992. Most of the woodland is burned every 1-3 years, which prevents the woodland reaching its maximum biomass.

METHODS

Methods are given in full on the Plan Vivo website under *Sofala Community Carbon Project Project Design Document According to CCB and Plan Vivo Standards*. Here we present an outline of the structure and protocols [100].

1. Carbon project principles and Plan Vivo

The Mozambican carbon project was the initiative of a commercial company, Envirotrade Ltd., with the role of *project developer* [102]. The developer's management role was (i) to *define and delineate areas of land* which are suitable for carbon sales, (ii) to alert potential carbon buyers of the offsetting opportunity the project presented, (iii) to gain the trust of the recipient *communities*, (iv) to negotiate contracts with local *farmers*, (v) to train the farmers to carry out specific management practices which are defined as *Technical Specifications.* The project developer also carries out day-to-day business management through its Mozambiquan subsidiary company: to keep the records of activity which form the basis of *payments*; these records may be interrogated later by the *carbon buyers* enabling them to personally verify that carbon stocks are being protected and enhanced. To satisfy requirements of the certification agency, there is a comprehensive *Project Development Document (PDD)* to enable the *Certifier* to issue certificates as *Voluntary Emission Reduction Units* (VERs) which subsequently might be traded as part of a carbon trading system. The voluntary carbon standard chosen when the project started in 2003 was the Plan Vivo standard, one of the first in the field, which has developed a reputation for carbon projects with a strong component of community development. After the selection of Plan Vivo, it was necessary to engage *external technical experts* to establish carbon *baselines* (a carbon baseline is the expected carbon sequestration potential without the project), and write *Technical Specifications* to define procedures [103]. Baseline data collection included estimation of deforestation rates, analysis of concentrations of carbon and nutrients in the soil, and socioeconomic status. Following the initial data collection, there must be a plan for *periodic monitoring* of the area covered with woodland, and the carbon stocks per area of land. This will now be done by a contract between the project developer and independent technical experts at the Eduardo Mondlane University in Mozambique.

The interaction between these components may be hypothetically represented by a block diagram (Fig 1). The income stream from carbon buyers is paid into a *Trust Fund* which is fully audited and consists of representatives of a local *Community Association* and other respected NGOs as well as a representative on the project developer. The carbon trust fund disburses funds to the farmers and makes funds available for local community projects, including the building of schoolhouses and a clinic, as well as funds for the development of micro-industries including tree nurseries, bee-keeping, a saw mill and carpentry shop (these activities stimulated business skills in the community). The Project Developer needs to cover costs, which include: staff salaries, vehicles, commissioned research and training, and third party audits.

2. Contracts with farmers

The basis of contracts was a set of Technical Specifications [103]. These are land management instructions with a table to show how much carbon is expected to be sequestered as a result of following the protocol. The first seven Technical Specifications in the project were for tree planting aimed at increasing carbon stocks in the land used for growing crops (agro-forestry with an emphasis on N-fixing trees, or orchards and woodlots). Then followed one further Technical Specification designed to reduce the rate of deforestation *Reducing greenhouse gas emissions by avoiding deforestation*. To incentivise farmers, payments were *ex ante*, based on previous experience of the Plan Vivo Foundation: immediately after planting the farmer received 30% of the payment, then 12 % per year for five years, then a final payment of 10 % in the seventh year. Thereafter, it is assumed that the benefits (fruits, crop improvements) of the plantings are clear to see, and the farmer will be unlikely to cut the trees.

3. Biomass estimation

Stem and root biomass was calculated from an inventory of 60 plots and a new allometric model, obtained from the destructive harvest of 29 trees, that relates diameter to stem and root biomass. The 60 plots were recorded between 2004 and 2007. The growth rate was obtained from the repeated measurement of trees at 15 one-hectare sample plots.

4. Remote sensing of deforestation rate

Originally we planned to use LANDSAT to estimate current deforestation rates but following the failure of its sensor in 2003 we used SPOT 4 images at 20 m resolution for 1999 and 2007. At the end of the project, we began to use Synthetic Aperture Radar (the ALOS sensor, the Japan Aerospace Exploration Agency) to attempt to measure biomass from space [6]. We see the Radar option as the means by which project leakage will in all carbon projects be monitored at regional and national levels.

5. Baselines

We considered three candidate methods of arriving at a carbon baseline for woodland. The first involves tracking the deforestation over the last few years using remote sensing and assuming that ‘without a project’ the rate would continue linearly. The second involves modelling the per capita destructive exploitation of woodland, and linking it to a model of how the population might grow over the coming decades in the absence of a project. The third, known as the ACEU method, assumes that if the land is **a**ccessible, **c**ultivable, has **e**xtractive value, and is **u**nprotected, then it *will* be deforested unless there is a specific intervention for conservation [102].

RESULTS

1. Carbon stocks

The carbon stocks as above-ground biomass in sample plots from woodlands ranged from 5 to 60 tons C ha^{-1}, with a mean of 29.9 tons C ha^{-1} (Fig 2). This is much less than for the typical carbon stocks of rain forest (~200 tons C ha^{-1}) [7], or for the uplands of Mexico where the original Plan Vivo project was established [101]. The permanent sample plots showed a Current Annual Increment of between 1 and 3 m^3 ha^{-1} $annum^{-1}$, comparable to the data available for this region from the National Forest Inventory, which is 1.2 m^3 ha^{-1} $annum^{-1}$. The latter implies a carbon sink of about 0.3 ton ha^{-1} $annum^{-1}$ provided the site is not burned. When burnt, to convert to machambas, the trees are not entirely destroyed, the mean residual biomass being 2.8 tons C ha^{-1}.

The carbon stocks likely to accrue over 100 years as biomass on machambas, estimated from current knowledge of the species, range from 10 tC ha^{-1} for *Gliricidia* interplanting, to 50 tC ha^{-1} for a managed woodlot. For the purposes of this article, we assume a conservative average of 20 tC ha^{-1}.

2. Areas of land with project activities

The area of land occupied by project activities increased rapidly over the period of the project. By late 2008 the area delimited and enumerated for avoided deforestation was around 10,000 ha; it provided a resource of saleable carbon which greatly exceeded the current sales (Table 1). The take-up of agroforestry options was good, although initially many farmers opted for the least intensive Technical Specification, namely Boundary Planting which provides relatively little carbon sequestration (Table 2). Later, many of these farmers added further Plan Vivos, to extend their involvement and therefore to increase their carbon sequestration and income. Ultimately, the two categories of land use are not independent, as it is through the adoption of agroforestry (a sustainable land use, to replace slash-and-burn) that encroachment onto forested lands is avoided.

3. Co-benefits and community involvement

By late 2009 there were 1,422 villagers with over 2500 hectares of land devoted to agroforestry practices carried out according to the Technical Specifications (Table 2). Participating farmers were trained in tree planting, harvesting, irrigation, composting and the community technicians in record-keeping. Tree nurseries were established to on a commercial basis to provide planting stock at a rate of 180,000 per year: the 17 workers were trained in seed collection, soil mixing, and general nursery techniques. They were initially formally employed and later they formed micro-enterprise companies. An office was established to deal with personnel issues, monitoring and record keeping for Plan Vivo: this formally employed 17 people. Fire management operations required 27 people in part time employment. Some technicians were trained and employed to collect data from sample plots and to carry out basic science activities. Various micro-enterprises were successfully established from carbon revenues, as a means to increase and diversify the community's income. As well as the nurseries, these were saw mill, carpentry, bee-keeping, keeping guinea fowl, turkeys and ducks, and the production of saleable crops. Socio-economic indicators were obtained by interviews with occupants of 245 households in 2004 and repeated survey in 2008. Cultivation of commercial crops increased from 23% of households to 73%, the number of households with livestock increased from 58-89%, employment of householders rose from 9 to 32%, and there was a small increase in literacy. Almost all of this benefit came from project activity (there were a few community members who made charcoal and sold it by the roadside but most charcoal makers were itinerant). We note that there are substantial differences in the initial starting conditions between the Plan Vivo project in Mexico [100] and those in the present project where there is a much lower level of employment and literacy, a much poorer standard of health and a lower and less predictable rainfall.

4. Remote sensing of deforestation rate and baselines

The deforestation rate over the period 1999 to 2007 was assessed as 2.4% per year, although there is a high degree of uncertainty in this estimate. If this rate were to continue linearly, there would be no remaining woodland in 42 years. An analysis of the rate of use of woodlands by a rapidly growing population revealed that the assumption of linearity, implied by this method of calculating a baseline, was not realistic. The baseline approach chosen was therefore the ACEU method, as the landscape is indeed **a**ccessible (> 8 km from a main road), **c**ultivable, **e**xtractable and, in the absence of a project, **u**nprotected. Thus, for carbon sales relating to avoiding deforestation, the assumption made is that the carbon would *all* be lost in the absence of a project, except for the few trees remaining after clearance for cultivation.

5. Cost of carbon capture

The saleable carbon is expressed as Voluntary Emission Reduction Units (VERs) in units of tCO_2. By July 2009 they were 979,788 tCO_2 available of which 156,085 tonnes were already sold at an average price of 8.62 $ per tCO_2, yielding 1,331,620 $. The buyers came from several countries, and included private individuals, consortia, and businesses; there was a strong representation from the entertainment industry. An additional research-oriented income of 2.47 million dollars came from the European Union, and so the total input to the project was 3.8 million dollars. The cost of capturing carbon so far may thus be estimated as 3.42 dollars per tonne of CO_2 sequestered. Currently, this is less than the price of carbon on the voluntary carbon market (Fig 3), leaving a profit margin. However, actual revenues have been less than this because not all the CO_2 that has been sequestered (in business terms, the 'stock') has yet been sold.

6. A business model

In this section we show how the income stream from carbon sales is allocated (Fig. 4). The Envirotrade model is that two thirds of all carbon finance is returned directly into the local economy of the country. Money from the remaining third will pay verification, validation and business costs.

One-third for farmers and community grants

To incentivise farmers, payments need to include an 'up-front' instalment, followed by further instalments which are conditional on progress (e.g. were the trees planted properly, have they survived?). Farmers are paid on the basis of inspections irrespective of whether the carbon offsets have actually been sold, an important feature that reflects the poverty alleviation objectives of the model. There is a fixed fee per contract on each tonne of carbon dioxide equivalent sequestered through agro-forestry of 4.46 $. REDD activities also generate income for each community member irrespective of whether they have a contract for agro-forestry at a rate of 1.3 $ to the community and 0.41 $ to the trust fund per protected hectare. These payment rates to individuals are set to provide an appropriate incentive (the agroforestry activity involves greater effort than fire management work).

One third for operations costs

One third is paid as operations costs to the project developer's *non-profit local subsidiary*, staffed and run by Mozambiquans 'Operations' includes the day-to-day running of the carbon project, including vehicles, materials, and employment. If the sales exceed the money needed for contractual and operations costs the balance is directed to the community trust fund, which may provide grants for other community-related activities such as construction of new school buildings, health clinics, and micro-enterprises. The greater the sales, the greater the funds available to the community trust fund as the operations budget will remain the same while the money available is larger. This brings a tangible effect from the buyer to the community.

One third for the parent company (the project developer).

This covers all off-site and international administrative, research, project development and marketing costs and may provides the Company with a profit. The parent company took on the responsibility of covering any shortfalls at the community trust by extending interest-free loans. These short-falls arise where carbon is sequestered by project activities and is not immediately sold. Any profits retained by Envirotrade were a small proportion of total offset credit sales, and were used (along with other financing sources) to cover the development costs of new projects. A maximum of 8% is retained from total carbon sales as a management fee.

6. Success as measured against initial criteria

All the initial criteria of success were achieved, i.e. carbon stocks of miombo woodland were measured, agroforestry systems were established, baselines were defined as far as possible, carbon sales exceeded $200,000 and there were significant co-benefits to the community. More offsets were sold for avoided deforestation than for tree planting. One may argue that avoided deforestation *now* is more valuable to the sequestration of carbon over decades to come. However, in this project the selling price of carbon is the same irrespective of the system used (Table 1).

DISCUSSION

The challenges encountered during the pilot project were significant, and the costs of start-up were therefore higher than anticipated. The main issues are listed here; items i, ii and iii are carbon accounting issues whereas iv relates to the special conditions of this part of Mozambique.

(i) The estimation of carbon content of a tree depends on appropriate allometric relationships being available. We found a number of allometries had previously been determined for woodland savanna but when we compared them with each other we found they yielded quite different estimates, especially in the case of large trees. So we embarked on a programme of sampling trees to determine allometric equations that were specific for the project area [8].

(ii) Baseline values for carbon content per area of land were not easy to establish by the accepted methodology defined by the IPCC Guidelines. The landscape in degraded Miombo is highly heterogeneous and the average for the region as a whole is unlikely to be the same as that of the parcels of land which are chosen for carbon sales. Specific enumeration is therefore required for each delineated parcel of land.

(iii) We had hoped to use LANDSAT-7 data to estimate current deforestation rates, so that these could be used to define baselines. However, LANDSAT-7 developed a fault in 2003, with no prospect of repair in the project's life time. We used SPOT data instead of LANDSAT-7 data to make vegetation maps, but acquiring cloud free imagery at the times of year when grass and tree biomass can be distinguished was difficult. Moreover, the optical satellite data cannot distinguish levels of degradation in Miombo ecosystems. At the end of the project we began to work with radar satellite data from Mozambique, as it became available from the Japanese ALOS sensor. The advantage of this approach is that radar penetrates the vegetation and gives completely different signals for woodland versus grass, and can even be used to estimate biomass [6]. Early results are very promising but ALOS is expected to continue only to 2011. For tracking changes in land use in woodland savanna, new satellite systems are required, based on radar.

(iv) The project operated in peculiar circumstances: rural communities in central Mozambique were in the aftermath of a bitter Civil War (1977-1992) and consequently there was an acute poverty in social capital. This meant that the challenges to governance and community management were acute. Therefore, components of the project developed rather slowly and at different rates, and the business model evolved over the course of the five years. At the end of the five years of EU funding, some parts were still under-developed but they were addressed in the sixth year.

Some further issues relate to the level of 'readiness' of local people for this type of carbon project. Two aspects may be briefly mentioned. First, the paradigm that people in other parts of the world are prepared to pay money to enable the planting of the trees whilst not owning those trees is completely new to the community and seems 'too good to be true'. Second, the culture of fire protection and management, in which one has to periodically light fires for 'prescribed burning', thus releasing CO_2 to the atmosphere, may be hard to understand. Indeed the whole concept of a global carbon cycle involving natural processes is novel to such a community. We have addressed this by means of teaching materials displayed in the local school house, and participation in courses given at the six local schools.

In the context of savanna woodlands, the potential to use them as a means to protect the climate system opens many possibilities; moreover, it is one possible route to sustainable development. For miombo alone, the biomass carbon stocks of the 2.7 million km^2 covered may be conservatively estimated as 40 billion tonnes, more than 10 times the annual emission of fossil-derived carbon for the entire planet. Moreover, the value of this carbon, assuming 10 dollars per tonne of CO_2 (or 37 dollars per tonne of carbon), is 1.45 trillion dollars. To this may be added further carbon stocks of other types of African savanna, of which mopane is the most significant. Many of the savanna regions are large and hold rich biodiversity, so the benefits are not just carbon-related. The benefits extend to nature conservation and the sustainable development of the region. We see already an improvement is socio-economic indicators when comparing the start and end of the pilot phase of the project. Linked to carbon income has been the development of micro-industries, that have provided further income through external sales, and which have also encouraged the development of business skills.

The income derived from carbon trading in the voluntary sector depends on the availability of buyers. The cost of producing carbon offsets by this method, estimated above to be 3.4 $ per tCO_2 by the time all currently available stocks have been sold, may be compared with the 1-5 $ per tCO_2 for a project in Nepal Himalaya [9] and a range of 0 to 200 $ per tCO_2 reported in a review of many forestry projects [10]. It is likely that the costs in the present project will now come down further as the activities extend to new areas including other parts of Mozambique, because the procedures are now well established and economies of scale are possible. The price at which carbon has been sold by the project has tracked the average for the voluntary carbon market, often exceeding it. But price depends on the state of the carbon market, which is still in its early stages of development. The market is sensitive to changes in the world economic order; indeed, there was a drop in all sectors of the carbon market in 2009. Hopefully it will recover. In the meantime, the shortfall in carbon buyers clearly poses a management problem, as for any business where production rates exceed sales. In this project, interest-free bridging loans have been secured and so the survival and development of the company has not been jeopardised.

An important question to address here is: for climate change mitigation, are there cheaper alternatives appropriate to this region of rural Africa? We thought of two possibilities. The tried the first, to cultivate *Jatropha* as an oil crop; the attempt resulted in limited success and might form the basis of a future project. The second, to use solar ovens for cooking instead of biomass burning, has been tried by others. Some successes have been reported but we have not been able to find an economic analysis.

Comparison is sometimes made between the costs of climate mitigation by forestry measures versus other geo-engineering solutions. A recent report found afforestation to be the most affordable technology, much cheaper than its nearest rival which was the use of stratospheric aerosols [11]. For most geo-engineering, the exact costs are not clear because all of them are in the pilot phase. Likewise, in avoided deforestation there are many uncertainties which will take decades to resolve [12].

Meanwhile, we see the development of another source of funding to avoid deforestation, based not upon project level funding but on reduced deforestation at national level. The current global model of REDD is currently being advanced by a group of countries who have together pledged more than 3.5 billion dollars over the next two years towards REDD. Southern Africa, and especially the miombo region, might be one of the recipients of such funding [13]. REDD funding would go to the relevant government ministries, and it would be up to them to decide whether to implement REDD through their own agencies or to subcontract to companies who have developed expertise through specific pilot projects. There will be major governance challenges of any future REDD to ensure that deforestation is *actually* avoided and to see that payments do, at least in part, benefit local communities.

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Table 1 Carbon stocks and their value in the two land uses of the project. Carbon stock per hectare has been multiplied by 3.66 to convert to CO_2. Value estimated at market price of 10 $ per tonne CO_2. The analysis covers the period 2003-2009.

Land use	Area delineated (ha)	CO_2 ha^{-1}	Saleable CO_2 (tonnes)	Sold CO_2 (tonnes)	Value of saleable CO_2 Million$ at 2009
Planting	2,877	73.2	210,596	54,629	2.1
Avoided deforestation	9,301	82.7	769,192	101,455	7.7

Table 2 Areas under tree planting and agroforestry, and the financial barriers (start-up costs and maintenance costs in the early stages of the plantation). Information from Envirotrade's Project Development Document obtainable at the Plan Vivo website [100].

Type of tree planting	Hectares under contract	Households signed up	Start-up costs	Annual maintenance costs
Boundary planting	1721	1428	25 $/100m	10 $/100m
Dispersed inter-planting	997	886	145 $/ha	62.5 $/ha
Fruit orchard with cashew	64	95	480 $/ha	200 $/ha
Fruit orchard with mango	55	57	520 $/ha	200 $/ha
Homestead planting	57	330	480 $/ha	200 $/ha
Woodlot	103	103	1,100 $/ha	430 $/ha

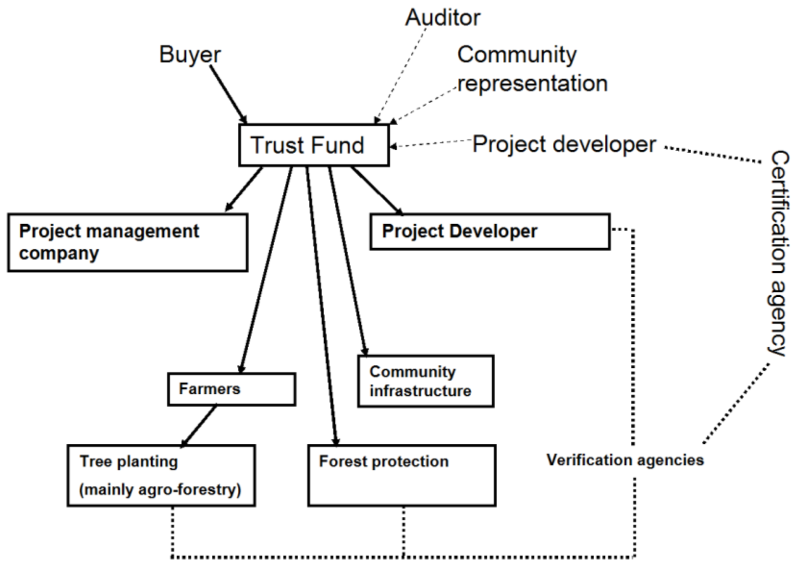

Fig 1. Generalised diagram to show the flow of money (solid line) in a project to incentivise tree planting and forest protection. Dashed lines signify activity of external agents.

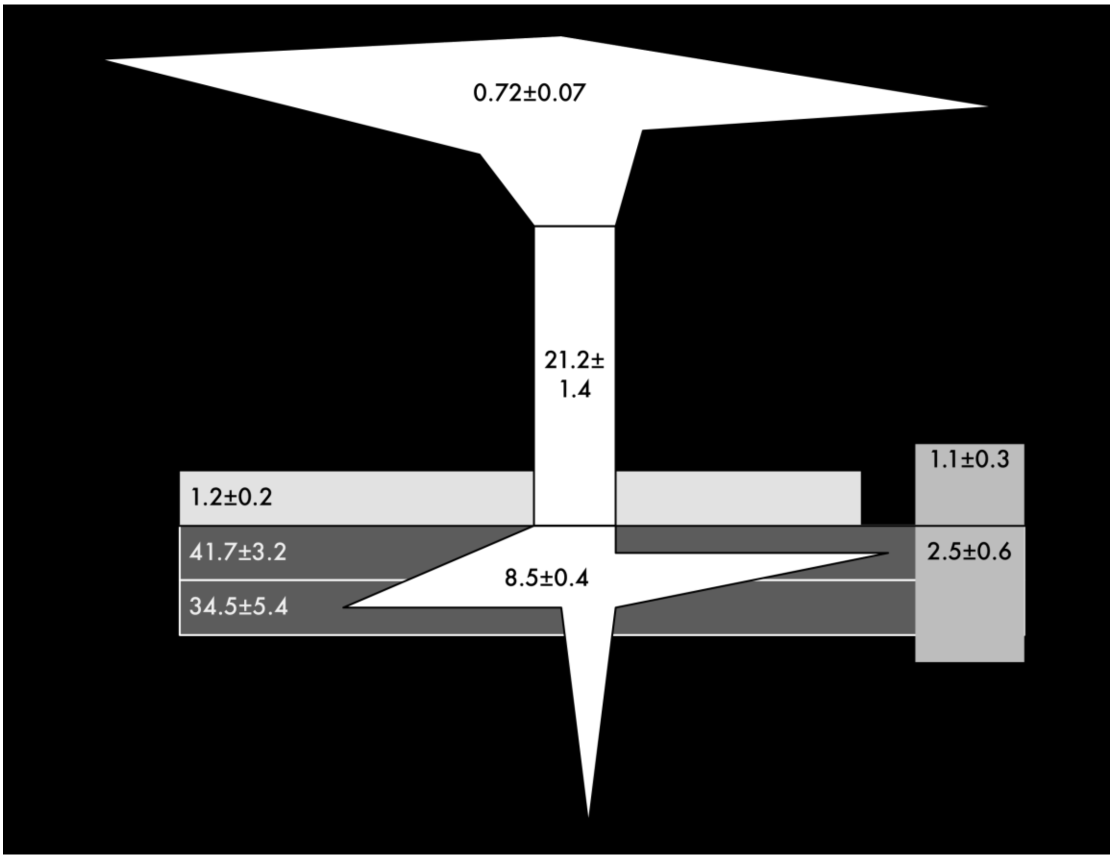

Fig 2 Measured carbon stocks in the miombo woodlands. Trees are defined as >5cm DBH, saplings as <5cm DBH, but>0.3mm D at 10 cm above the ground. Stocks are for annual maxima of grass and leaf biomass. All stocks are in tC ha^{-1}, ± standard errors of the means. Stem and root biomass were calculated based on the inventory of 58 plots (total area 27.2 ha). On conversion to farmland not all carbon is removed, and we estimate the carbon lost as 22.5 tC ha^{-1}.

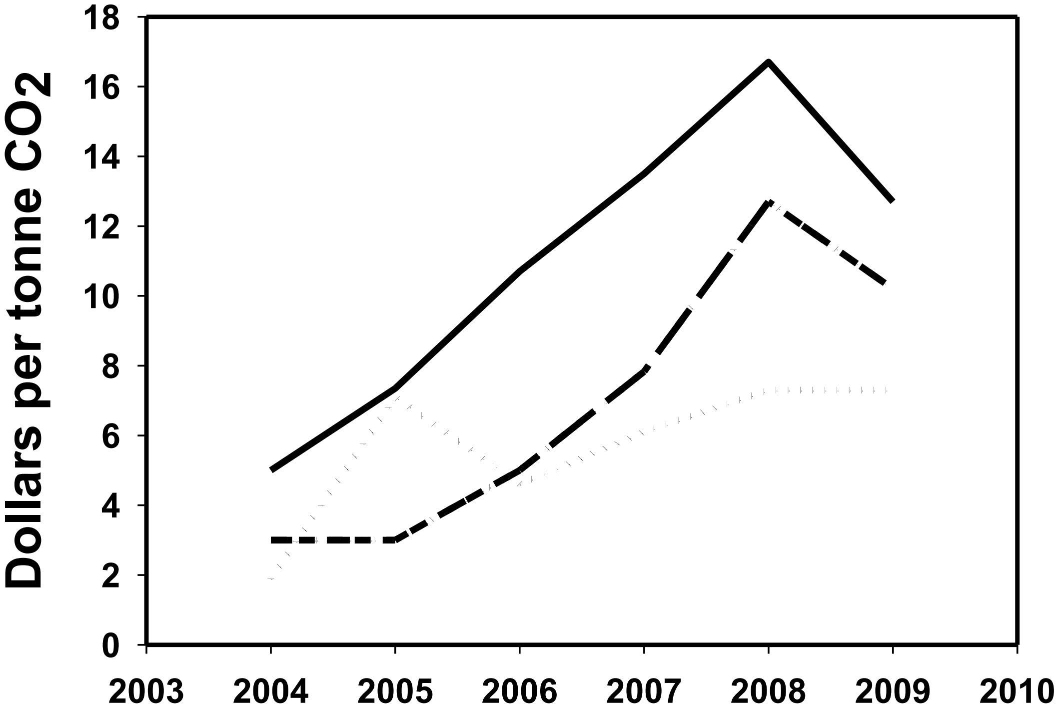

Fig 3 Trends in market prices over the course of the project. The solid line shows market prices for the Clean Development Mechanism (CDM) of the Kyoto Protocol, the dotted line shows the average for the voluntary sector (data from the World Bank archives), and the dashed line shows prices of the sales pertaining to the current project.

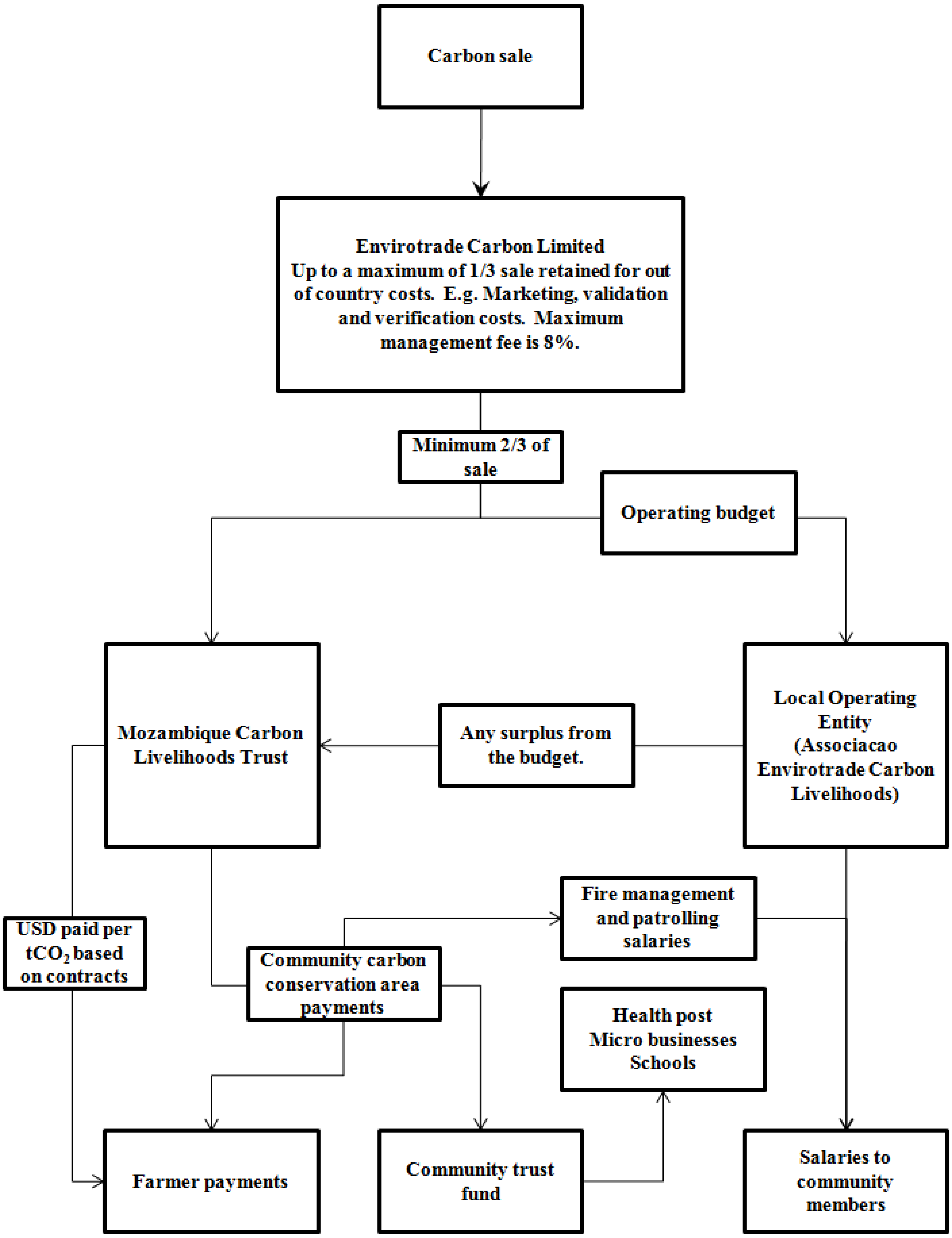

Fig 4. Specific diagram to show business plan for revenues from carbon sales in the Sofala carbon livelihoods project.